

Riparian drivers and the relative effect of fine sediment and nutrients on invertebrate communities in agricultural streams

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Agricultural production is required to become more intensive to support the world's increasing population (Vitousek et al., 1997). As a consequence, the excessive demands on finite resources are expected to cause large-scale ecosystem simplification, loss of ecosystem services, and species extinctions (Tilman et al., 2001). Agricultural land uses impact streams by changing riparian and channel habitat, reducing bank stability, altering flows and increasing inputs of pollutants, including fine sediment and nutrients (Allan, 2004). In particular, the diffuse release of these pollutants is a widespread and pervasive problem in waterways globally. This has led to an appreciation of riparian processes and their contribution to stream ecological integrity, meaning the use of riparian buffers has been widely accepted as a way to mitigate diffuse pollution associated with agricultural land uses (Lowrance, 1998).

Suspended sediment and elevated concentrations of nutrients can affect aquatic organisms directly and indirectly through increased turbidity, abrasion, toxicity, and eutrophication leading to hypoxia. However, the impact of these pollutants also includes effects through the alteration of the physical habitat and food resources. This can contribute to marked changes in plant, invertebrate and fish community composition (Allan, 2004). With a growing emphasis on maintaining the ecological integrity of waterways, research has shifted from focusing on specific components of freshwater habitats to embracing a community and ecosystem perspective (Sandin and Solimini, 2009). This means that understanding the effects of sediment and nutrients on stream communities and identifying threshold responses is crucial in helping to maintain ecosystem function and biodiversity of habitats under increasing anthropogenic pressure.

Thirty lowland agricultural streams on the Canterbury Plains were sampled along dual fine sediment and nutrient pollution gradients in an orthogonal design. Agricultural activities on the Plains are dominated by cropping, sheep and increasingly intensive dairy farming. The primary aim of this research was to examine how these two stressors, commonly associated with agricultural land uses, affect invertebrate communities. A secondary objective was to better understand how agricultural processes affecting riparian condition influence in-stream habitat. The physical and biotic variables recorded included nutrients, transportable sediment substrate composition, aquatic invertebrates, and flow characteristics at the reach scale. Riparian condition was assessed at the segment scale. The nutrient and sediment gradients ranged from 0.03-8.79 mg/L NO₃-N and 0.89-1430 g/m² transportable sediment respectively. The latter was highly correlated with alternative measures including a substrate index and the percentage cover of fine sediment on the streambed.

Nutrient and sediment levels had strong effects on faunal diversity, composition and traits. Nutrient levels (mg/L NO₃-N) had a strong negative association with invertebrate diversity, whereas taxa richness only showed a weak decline along the sedimentation gradient. However, the effect of deposited sediment was greater in driving patterns of faunal composition and traits. Pollution-sensitive EPT taxa were disproportionately affected with a 77% reduction in taxa richness and the percentage composition of this group (Figure 1.1) demonstrated a negative sigmodal dose response ($R^2 = 0.894$, $P < 0.001$), suggesting a potential threshold of 20% fine sediment covering the streambed. Furthermore, average invertebrate body size decreased along the sediment gradient ($R^2 = 0.742$, $P < 0.001$), potentially leading to indirect effects on higher consumers and indicating a possible trait for

measuring sediment-specific impacts in streams. Further investigation of faunal traits suggests it is possible to discern the relative effects of sediment and nutrients upon stream invertebrate communities.

Identifying the principal pathways of diffuse pollution in agricultural catchments is essential to devising effective mitigation practices. Substrate composition showed a strong negative association with degraded riparian condition even after accounting for the effects of flow, and two riparian properties (soil pugging and compactedness, the number of rills and channels) were identified through hierarchical partitioning as having statistically significant associations with levels of fine sediment. Despite this, spatial and temporal legacy effects are prevalent in lowland agricultural streams. For example, the relationship between riparian condition and nutrient status was unclear, most likely reflecting local Canterbury Plains conditions on the where the groundwater streams are enriched via aquifers; a process often spatially distinct from recharge of unconfined independent of and riparian zones.

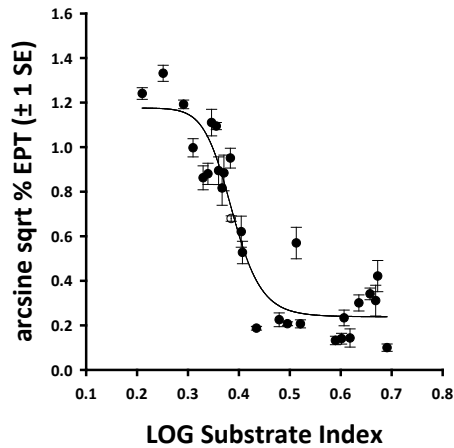


Figure 1.1 The percentage composition of pollution-sensitive EPT taxa demonstrates a negative sigmodal relationship ($R^2 = 0.894$, $P < 0.001$) along the sediment pollution gradient, represented here by a modified version of the Jowett & Richardson substrate index. Higher values of the substrate index equate to a greater percentage cover of fine sediment (<2mm) on the streambed.

Despite the heavily modified landscape of the Canterbury Plains and the associated impact upon stream invertebrate communities, these results show distinct responses to different stressors. This further demonstrates the importance of measuring multiple stressors and their effect upon stream ecosystems. Sedimentation and nutrient enrichment have independent and synergistic effects resulting in changes to invertebrate diversity, composition, and faunal traits. Furthermore, it may be possible to use invertebrate traits to biomonitor for the relative importance of different stressors, thus helping to mitigate the effects of which have different underlying causes. Ultimately, however, understanding interactions between multiple stressors is crucial to mitigating land use impacts whilst preserving ecosystem function and biodiversity. For example, in lowland agricultural streams, complex interactions may exist between excessive inputs of light, nutrients, fine sediment and the growth of macrophytes, which then contribute to the hysteresis of stream ecosystems via decreased velocities and enhanced sediment retention; a process independent of, but potentially exacerbated by base flow conditions (Matthaei et al. 2010). The non-linearity of such complex ecological systems challenges scientists to forecast when thresholds of harm will be reached and what the ecological consequences will be. This demands a better understanding of how the cumulative pathways of perturbations affect ecosystems.

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